The Effect of Maturity, Handling and Processing Conditions, Freezing Methods, on the Development of Fragile Roe and on Roe Yield from Impounded and Wild Stocks of Herring, 1984

H. Tsuyuki and J. Y. H. Cheng

Department of Fisheries and Oceans
Fisheries Research Branch
Vancouver Laboratory
Vancouver, British Columbia V6T 1X2

November 1985

Canadian Technical Report of Fisheries and Aquatic Sciences No. 1411

86-03497/

Canadian Technical Report of Fisheries and Aquatic Sciences

Technical reports contain scientific and technical information that contributes to existing knowledge but which is not normally appropriate for primary literature. Technical reports are directed primarily toward a worldwide audience and have an international distribution. No restriction is placed on subject matter and the series reflects the broad interests and policies of the Department of Fisheries and Oceans, namely, fisheries and aquatic sciences.

Technical reports may be cited as full publications. The correct citation appears above the abstract of each report. Each report is abstracted in *Aquatic Sciences and Fisheries Abstracts* and indexed in the Department's annual index to scientific and technical publications.

Numbers 1–456 in this series were issued as Technical Reports of the Fisheries Research Board of Canada. Numbers 457–714 were issued as Department of the Environment, Fisheries and Marine Service, Research and Development Directorate Technical Reports. Numbers 715–924 were issued as Department of Fisheries and the Environment, Fisheries and Marine Service Technical Reports. The current series name was changed with report number 925.

Technical reports are produced regionally but are numbered nationally. Requests for individual reports will be filled by the issuing establishment listed on the front cover and title page. Out-of-stock reports will be supplied for a fee by commercial agents.

Rapport technique canadien des sciences halieutiques et aquatiques

Les rapports techniques contiennent des renseignements scientifiques et techniques qui constituent une contribution aux connaissances actuelles, mais qui ne sont pas normalement appropriés pour la publication dans un journal scientifique. Les rapports techniques sont destinés essentiellement à un public international et ils sont distribués à cet échelon. Il n'y a aucune restriction quant au sujet; de fait, la série reflète la vaste gamme des intérêts et des politiques du ministère des Pêches et des Océans, c'est-à-dire les sciences halieutiques et aquatiques.

Les rapports techniques peuvent être cités comme des publications complètes. Le titre exact paraît au-dessus du résumé de chaque rapport. Les rapports techniques sont résumés dans la revue *Résumés des sciences aquatiques et halieutiques*, et ils sont classés dans l'index annual des publications scientifiques et techniques du Ministère.

Les numéros 1 à 456 de cette série ont été publiés à titre de rapports techniques de l'Office des recherches sur les pêcheries du Canada. Les numéros 457 à 714 sont parus à titre de rapports techniques de la Direction générale de la recherche et du développement, Service des pêches et de la mer, ministère de l'Environnement. Les numéros 715 à 924 ont été publiés à titre de rapports techniques du Service des pêches et de la mer, ministère des Pêches et de l'Environnement. Le nom actuel de la série a été établi lors de la parution du numéro 925.

Les rapports techniques sont produits à l'échelon régional, mais numérotés à l'échelon national. Les demandes de rapports seront satisfaites par l'établissement auteur dont le nom figure sur la couverture et la page du titre. Les rapports épuisés seront fournis contre rétribution par des agents commerciaux.

Canadian Technical Report of

Fisheries and Aquatic Sciences No. 1411

November 1985

THE EFFECT OF MATURITY, HANDLING AND PROCESSING CONDITIONS, FREEZING METHODS, ON THE DEVELOPMENT OF FRAGILE ROE AND ON ROE YIELD FROM IMPOUNDED AND WILD STOCKS OF HERRING, 1984

by

H. Tsuyuki and J. Y. H. Cheng

Department of Fisheries and Oceans

Fisheries Research Branch

Vancouver Laboratory

Vancouver, British Columbia V6T 1X2

(C)Minister of Supply and Services Canada 1985

Cat. No. Fs 97-6/1411E ISSN 0706-6457

Correct citation for this publication:

Tsuyuki, H. and J. Y. H. Cheng. 1985. The effect of maturity, handling and processing conditions, freezing methods, on the development of fragile roe and on roe yield from impounded and wild stocks of herring, 1984. Can. Tech. Rep. Fish. Aquat. Sci. 1411: 29 p.

TABLE OF CONTENTS

	Page No.
INTRODUCTION	1
MATERIALS AND METHODS	2
Source of herring and sampling from impoundments	2
Roe processing	2
Source of herring and sampling from wild stocks	3
Grading	4
RESULTS AND DISCUSSION	4
QUALITY OF ROE FROM HERRING OBTAINED FROM:	4
(a) Brandon Island impoundment site	4
(b) Whaleboat Passage impoundment site	6
(c) Wild stocks of herring	6
RELATIONSHIP BETWEEN MATURITY AND FRAGILITY	7
EFFECT OF HANDLING AND PROCESSING METHODS ON ROE QUALITY	7
(a) Influence of brine concentration and firming time on the development of fragility	7
(b) Effect of contact in salt solutions of various strength on the development of fragility	8
(c) Effect of handling and preservation methods prior to processing on the quality of roe	8
(i) dry holding at ambient temperatures followed by preservation by slow and fast freezing	8
(ii) holding in seawater strength brine at ambient temperatures prior to preservation by freezing	9
(iii) chilled storage followed by brine curing	9
(iv) review of findings	9
ROE YIELD	9
CONCLUSIONS	11
ACKNOWLEDGMENTS	12
REFERENCES	13
TABLES	14
FIGURES	23

ABSTRACT

Tsuyuki, H. and J. Y. H. Cheng. 1985. The effect of maturity, handling and processing conditions, freezing methods, on the development of fragile roe and on roe yield from impounded and wild stocks of herring, 1984. Can. Tech. Rep. Fish. Aquat. Sci. 1411: 29 p.

During its course of development immature roe must pass through a transitional phase just before maturation when by color, texture or size it becomes increasingly difficult to distinguish from the fully mature. All the immature and most of the near-mature roes can be distinguished from the mature during retrieval from fish after the brine firming step because of their failure to become firm. With sufficient care most of the near-mature roe which escaped detection at this stage can be identified during grading of the brine cured product.

Under good storage, freezing, frozen storage and processing conditions, fragile roe can be distinguished readily from the immature, and with some care from most of the near-mature. Even when the proportion of immature roe is high only a slight increase in fragile roe is encountered in the final product. Roe herring from upper Trincomali Channel, Deep Bay and Barkley Sound did not differ in their tendency to develop fragile roe and the incidences were very low. The use of poor freezing and frozen storage practices promoted the development of both spongy and fragile roe. The two conditions were difficult to distinguish when sponginess was extensive.

Immersion of herring in fresh water for 3 days at a temperature of 5°C resulted in the development of fragile roe to a significant level. After 5 days the level of fragility increased. Immersion in brine concentrations of 11% and higher reduced the development of fragility to a level below 5%, even after 7 days at this temperature. Brine-firmed roe immersed in fresh water at 5°C for 24 hours developed in excess of 30% fragility; those immersed in salt solutions ranging from 3.5% to saturation developed an average of 5% fragility.

Storage of herring for 2 days in the dry state or in 3.5% salt at ambient temperatures prior to freezing resulted in very low levels of fragile roe. However, at 5 days holding, followed by slow freezing, the deterioration into either fragile or the spongy condition was almost complete. Storage in chilled 3.5% brine for 2 to 5 days followed by brine curing resulted in the development of slightly under 5% fragility.

The proportion of normal quality processed product attained the highest levels about one week after the gonosomatic index reached its plateau. The amount of immature roe during that first week was still up to 15%.

The gain in weight of processed roes from once frozen impounded herring ranged between 10 to 14%. Those from wild stocks from Barkley Sound gained between 3 and 16%. Fish held for 3 days in the dry state or in 3.5% brine at ambient temperatures before freezing resulted in gains of 9 to 16% while those held for 5 days gained 3 to 4%. Gain in roe weight of 7 to 8% after processing was observed from unfrozen fish.

RESUME

Tsuyuki, H. and J. Y. H. Cheng. 1985. The effect of maturity, handling and processing conditions, freezing methods, on the development of fragile roe and on roe yield from impounded and wild stocks of herring, 1984. Can. Tech. Rep. Fish. Aquat. Sci. 1411: 29 p.

Au cours de leur développement, les oeufs immatures doivent franchir diverses étapes pour atteindre la maturité, étape avant laquelle la couleur, la texture et la taille sont de plus en plus difficiles à distinguer de celles d'oeufs matures. Tous les oeufs immatures et la plupart de ceux qui sont presque matures se distinguent, lorsqu'ils sont extraits du poisson, des oeufs matures par leur manque de fermeté après le saumurage. En faisant suffisamment attention, on peut identifier la plupart des oeufs presque matures, qui n'ont pas été repérés à ce stade, lors du triage du produit traité à la saumure.

Grâce à de bonnes conditions de stockage, de congélation et de conditionnement, on peut distinguer aisément les oeufs fragiles des oeufs immatures et, en portant plus d'attention, de la plupart des oeufs presque matures. Même quand la production d'oeufs immatures est élevée, on ne trouve qu'une légère augmentation des oeufs fragiles dans le produit final. Les oeufs de hareng de chenal de Trincomali supérieur, de la baie Deep et de la baie Barkley présentaient tous une très faible tendance à la fragilité. Les oeufs sont devenus spongieux et fragiles après avoir été mal congelés et mal entreposés en chambre froide. Ces deux conditions ont été difficiles à distinguer dans le cas des oeufs très spongieux.

On a obtenu beaucoup d'oeufs fragiles en immergeant du hareng dans de l'eau douce à 5°C pendant trois jours. La fragilité a augmenté après cinq jours. Elle est retombée à moins de 5% après immersion dans une saumure de 11% ou plus, même après sept jours à cette température. Les oeufs affermis à la saumure, après immersion dans l'eau douce à 5° pendant 24 h, présentaient un niveau de fragilité de plus de 30%; ceux immergés dans diverses solutions salines (allant de 3,5% à la saturation) présentaient en moyenne une fragilité de 5%.

En entreposant de hareng pendant deux jours à sec ou dans une solution saline de 3,5% à des températures ambiantes avant la congélation, on a obtenu des oeufs très peu fragiles. Toutefois, après cinq jours dans ces conditions et avant une lente congélation, la plupart des oeufs sont devenus fragiles ou spongieux. L'entreposage au froid dans une saumure de 3,5% pendant deux à cinq jours, suivi d'un traitement à la saumure, a donné une fragilité légèrement inférieure à 5%.

La proportion de produit conditionné de qualité normale atteint son niveau le plus élevé environ une semaine après que l'indice gonosomatique ait atteint son plateau. Le pourcentage d'oeufs immatures au cours de cette première semaine s'est maintenu à près de 15%.

Le gain en poids des oeufs conditionnés de hareng confiné et congelé variait de 10 à 14%. Les oeufs de hareng sauvage du détroit Barkley ont augmenté leur poids de 3 à 16%. Le poisson maintenu pendant trois jours au sec ou dans une saumure de 3,5% à température ambiante, avant la congélation, ont vu leur poids augmenter de 3 à 4%. On a observé un gain de 7 à 8% en poids chez les oeufs de poisson non congelé, après conditionnement.

INTRODUCTION

This report describes the findings on the causes of the development of fragility in roe from both impounded and commercial sources of herring, the effect of maturity, the effect of handling, storage, and processing practices. Other quality aspects as well as the gain in yield of processed product from once frozen herring under different pre-freeze treatments are described.

During the course of investigations carried out at this laboratory on different aspects of herring roe processing (Boyd et al. 1972), including the quality of products formed, fragile roe has been encountered and reported several times (Tomlinson et al. 1975; Tsuyuki et al. 1977; Boyd et al. 1980). Aspects of processing factors affecting development of fragile roe were also reported by Huynh et al. 1984. Further studies on roe quality were conducted during 1981 - 83 (Tsuyuki and Cheng, unpublished) using herring from commercially available sources and from impoundment studies at the Pacific Biological Station (PBS) at Nanaimo (Brett and Solmie 1982; Kreiberg et al. 1982, 1984).

The impounded herring in particular provided an excellent opportunity to follow and assess roe quality from frequent sampling as fish in captivity gradually matured. The impoundment operation was considered the closest facsimile to a uniform population of herring to study the effect of maturity on the development of fragility. Fish from this source minimized post mortem delays prior to preservation by on-site quick freezing. Fragility caused by handling and freezing practices were therefore held to a minimum.

Previous studies (Tsuyuki and Cheng, unpublished) on roe from herring harvested in Barkley Sound indicated little or no development of fragility despite the lapse of about 24 hours prior to fast freezing of the fish at the laboratory. Analysis of commercial data on herring in which the degree of maturity was provided indicated some relationship between the incidence of fragility and the extent of immaturity of the fish. During the 1983 roe herring season, high incidences of fragile roe were reported by some sectors of the industry. A meeting was held on 11 January 1984, between the staff of DFO involved with herring and representatives of industry and B.C. Research to discuss and to present our collective experience with the problem of the development of fragile roe. From this meeting, several possible causes of fragile roe were identified: (1) the post-mortem handling time prior to processing; (2) the holding temperature of the fish; (3) biological factors related to geographic or demographic differences in maturity. The Fisheries Research Branch was involved in the analyses of these biological considerations.

An experimental approach to the study of the fragility problem was agreed to with the co-operation of the Herring and Aquaculture Sections of PBS. In a concerted effort the Technology Laboratory undertook to examine the quality aspects of the roe. The staff of PBS collected the required amount of samples for our 1984 quality studies as well as for their own investigations from their impoundment operations at Brandon Island and at Whaleboat Passage. The results of research by the Technology Laboratory, PBS, B.C. Research, and other research results were presented on 12 October 1984, before the Fisheries Council of British Columbia Technical Sub-Committee on Herring Roe. Copies of

our results dealing with the quality of roe from impounded herring were distributed to attendees at that meeting as were reports from PBS. During the summer months senior staff of the Technology Laboratory held extensive discussions with fishing company representatives of the province on technological aspects of fish quality including the problem of fragility in herring roe.

MATERIALS AND METHODS

SOURCE OF HERRING AND SAMPLING FROM IMPOUNDMENT

The herring were caught at the upper extreme area (north end) of Trincomali Channel, off Pylades Island, during the period 31 January to 4 February 1984, and were impounded at Whaleboat Passage and Brandon Island field sites until the gonad development of the fish approached the ripe stages. Fish were held until at least one week after gonad development peaked.

Herring in lots of 100 to 120 kg in 6 to 8 pails were sampled from the sea pens at Brandon Island, starting on February 28 and continuing once every three to four days until March 12. Sampling frequency was then increased to once daily for 9 more days and the size of lots increased to a total of about 200 to 240 kg. After March 21, sampling was reduced to once every three or four days until April 6, 1984. For each sampling, the roe herring was separated into 3 size ranges (large, 208 - 225 mm in length; medium, 196 - 207 mm; and small, 140 - 195 mm) and frozen in pails as soon as possible in commercially operated freezers at Nanaimo. Frozen roe herring samples were brought to the Technology Laboratory at Vancouver for processing and evaluation of quality.

ROE PROCESSING

(1) Brine firming method

Roe herring were immersed for 3 - 4 days in 10 - 15% (w/v) salt solution at around 5°C. The fish to brine ratio was 2:1 (w/v). At the end of this time the roe was generally firm enough to remove readily even at a lower temperature (Boyd et al. 1980). The roes were rinsed with water or 4% brine 2 to 3 times to remove debris and to minimize discoloration and then immersed in 10% brine overnight. After draining briefly the roes were tranferred to saturated brine (24 to 26% sodium chloride, w/v) for a day. The roes were then drained and immersed in fresh brine fortified with additional salt. After 5 - 7 days at 2 to 5°C, the roes were drained for approximately 2 hours, weighed and graded for quality.

(2) Processing method by freezing

About 15 - 20 kg lots of roe herring were placed in 46 x 81 cm polyethylene bags of 6 mil thickness, the open end folded and stapled. The bags of herring were placed on aluminum shelves in single layers in an air-blast freezer room at -40°C, spread out to a thickness of about 10 x 35 x 60 cms and

stored for a period of 1 - 2 months.

Some 15 kg lots of fish were frozen in a Dole horizontal double contact plate freezer. Thermocouples inserted in the belly cavity of fish placed approximately in the center of the bags measured -30°C within 8 hours (Fig. 1, fast freeze).

The frozen herring blocks were either air-thawed at 20 - 22°C or thawed in slowly running cool water for 1 - 2 days. The removal of roe [illegible] brine processing was carried out in the usual manner.

SOURCE OF HERRING AND SAMPLING FROM WILD STOCKS

(a) Sampling from seine boats

Through the co-operation of the Field Services Branch, DFO, roe herring were obtained from seine boats operating in different fishing areas of British Columbia. Two lots of herring from Deep Bay (Area 14), caught on February 20 and 25 were used as the early stock for the purposes of monitoring the development of roe fragility during maturation of wild stocks. Additional samples were obtained from Barkley Sound (Area 23) on March 8 and 12.

(b) Bulk sampling from the Gulf Islands

Two lots of herring were used to study the effect of brine firming and holding time on the development of roe fragility. The holding temperature was 5°C. The fish were caught by the seiner Pacific Quest at Stuart Channel (Area 17) on March 6, transferred to the vessel Chimo IV for holding in chilled seawater (CSW) system and landed at Ocean Fisheries Ltd. Portions of the herring, approximately 500 kg, were brought back to the laboratory for the experiments. The post-mortem age of the roe herring in CSW system was about 16 hours.

Lots of 23 kg of herring were placed in plastic tubs and immersed in various brine solutions (3.5%, 11%, 16% and 26% w/v) at a fish to brine ratio of 2:1 (w/v). The brine firming process was carried out at 5 ± 1°C for 3 to 7 days as described previously (Boyd et al. 1980).

For studies on the development of fragility in roe from the brine firming process followed by prolonged washing, the green roe obtained from 11% brine processed lot was rinsed briefly with tap water twice and then placed in various concentrations of brine solutions for up to 24 hours prior to curing. After curing and draining briefly, the roe was ready for grading and assessment of quality after 5 to 7 days at 2 to 5°C. The weights and numbers of skein were recorded after roe was drained well for approximately 2 hours.

(c) Bulk sampling from Barkley Sound

Seine caught test fish (762 kg) from Barkley Sound, obtained on March 13, 1984, were used to study the effect of holding conditions on the development of fragility in roe from once frozen herring. The herring was held on board the vessel Lasqueti Steeler in refrigerated seawater (RSW) system for about 22 - 24 hours prior to experimental processing of roe. Appropriate portions of fish were placed in suitable containers for the following experiments:

(1) Fast Freeze (FF): A Dole horizontal double contact plate freezer was used. Fish were loaded into aluminum trays of dimensions 6 x 26 x 50 cms and frozen. The core temperature of fish reached -30°C after about 8 hours (Fig. 1, fast freeze).

(2) Slow freeze (SF): Foster freezers pre-set at -10°C were used. Fish were loaded into perforated plastic trays of dimensions 10 x 34 x 47 cms. From an initial temperature of 10°C the core temperature of fish reached -1°C after about 8 hours (Fig. 1, slow freeze) and -5°C after about 48 hours.

(3) Chilled storage: fish were immersed in a mechanically refrigerated 3.5% brine solution in an insulated container of internal dimensions 61 x 61 x 81 cms.

Frozen herring blocks from (1) and (2) above were packed in polyethylene bags and stored at -30°C for 4 to 6 weeks prior to thawing and further processing. Herring blocks were thawed by immersing in initially lukewarm tap water and when the roe was firm enough, removed and processed in the usual manner.

GRADING

The processed roe was graded into four groups:

(1) Normal firm roe (N): measured physically by hand compression for acceptable quality roe. If required, firmness was determined with the Ottawa Texture Measuring System as described in Tsuyuki and Cheng 1985.

(2) Spongy roe (SP): opaque patches on the roe when squeezed due to leakage of cellular fluids through the damaged cell walls of eggs and resulting in the loss of crunchy texture on chewing.

(3) Fragile roe (FR): brittle and/or soft in texture; crumbling of the skein structure due to separation of the eggs.

(4) Unripe roe (UR) or immature roe: generally darker in color, soft and will not firm after processing.

The term "mature" roe as used here refers to those which become firm after brine curing, while "immature" or "unripe" roe refers to those which remain soft and cannot be firmed.

RESULTS AND DISCUSSION

QUALITY OF ROE FROM HERRING OBTAINED FROM:

(a) Brandon Island impoundment site

The proportion of roe in the unripe stage of development from large and

medium sized herring decreased from over 50% in the sampling of February 28 to a level of about 5% in the samples of March 18, 1984. Roes from small herring did not reach this level until March 21 (Tables 1a, b and c). Generally from the processing standpoint, roe from larger fish matured at a earlier time. This finding is consistent with the observations of Hay (1985) that later spawning fish are smaller in size. The amount of normal quality roe approached the highest level at around the third and fourth week of March.

Incidences of spongy roe ranging up to 36% were found during the entire sampling period in this study. Initially, the adequacy of the commercial freezers was tested by inserting a thermometer in a hole drilled through the center of the lid of the pail and lowered to approximately the center of the herring samples. A number of pails of herring tested in this way indicated that the freezing rate conformed to what we have established as a suitable practice previously (Tsuyuki et al. 1977). The commercial freezers used for frozen storage of samples was therefore considered adequate from the standpoint of freezing capacity and ultimate storage temperature. All routine sampling and frozen storage at Nanaimo were carried out by contract personnel engaged in this study. The level of sponginess encountered in this study was therefore unexpected. As a result of the large numbers of samples, it could have been brought about if the pails of herring were stacked closely together in the freezer in such a way as to limit circulation.

If good freezing and frozen storage practices could have been applied and the development of spongy roe circumvented, the yield of normal quality roe may have reached close to the highest levels a few days earlier in large sized fish. In Figure 2 the normal and spongy roe were combined to bring out this point. Roe from medium and small fish did not reach the highest level until the third week in March. The yield of roe of all quality before processing and calculated as percent of females only was found to be the highest from large fish and the lowest from small sized fish with that from the medium size fish falling somewhere in between (Fig. 3). These observations support the findings of Hay (1985) conducted on female herring captured over a much broader area of the coastal waters of British Columbia.

The results of a separate monitoring of the gonosomatic index (GSI) from samples drawn at the same times as those for studying the quality of processed roe are shown in Figure 4. These results, obtained at PBS by Mr. Harmon and co-workers, were kindly provided by Dr. Hay for inclusion in this report. The GSI is based on 200 female herring ranging in length from 196 to 204 mm. Julian day 72 in this figure corresponds to the first of the daily sampling beginning on 12 March. A comparison of Figures 2 and 4 revealed that the proportion of normal quality processed roe (normal + spongy, as explained elsewhere) that could be produced from the impounded herring reached maximum levels around 18 March, about one week following the time when the GSI reached a plateau level. During the initial week after reaching the plateau level of GSI as much as 15% of the roe were still not suitable for the production of normal quality processed product (Fig. 2). The proportion of immature roe (UR) during this period, as shown in Table 1b, is still substantial, accounting for the greater part of the lower yield of normal processed product. During this initial week, substantial numbers of roe were similar in size to the fully mature, though clearly identifiable as immature.

Grading for fragile roe in the presence of high incidences of spongy roe

was found to be difficult. The incidence of fragile roe from the study ranged from less than 1% to up to 9% (Tables 1a, b and c). The early sample on February 28 and March 2 produced up to 3 - 7% fragile roe even in the absence of spongy roe. These findings confirmed our observations from the previous two years on the study of incidences of fragility in roe from impounded immature herring which were quick frozen at the laboratory and held in storage at temperatures low enough to avoid development of sponginess.

Samples from March 8, 12, 13 and 18 with relatively high degrees of sponginess showed significant levels of fragile roe. When the processed roe was in an excessively spongy condition, it was not always easy to distinguish between this and the fragile condition. However, the fragile condition was easier to distinguish from the spongy state when the incidences of the latter condition were more moderate (March 16, 19, 27 and April 2 samples).

The final roe yield of the impounded herring during the peak period varied by size of fish. For the large size herring, the roe yield after processing ranged from 31% to 35% of body weight based on the female fish; medium size herring ranged from 27% to 30% while the small size herring ranged from 23% to 26%.

(b) Whaleboat Passage impoundment site

The herring from the Whaleboat Passage impoundment site were neither segregated by size nor sampled as frequently as those from the Brandon Island site. The earliest samples of February 28 were mostly immature (Table 2) while those from Brandon Island (Table 1a) sampled at the same time showed that about one-half the roe by weight were immature. By March 13, maturity assessment conducted on fish from this impoundment site indicated that over 80% of the female gonads were at stages IV and V on the international (Hjort) scale of maturity (Bowers and Holliday, 1961). The ovaries occupied almost two-thirds or more of the ventral cavity, eggs were swollen and transparent indicating that they were ready for processing. The level of maturity at this time were about the same as those from the average of the 3 size ranges from Brandon Island (Table 1b). Very little of the roe from Whaleboat Passage was spongy, indicating good freezing practices prevailed, possibly as a result of smaller quantities frozen. These results also indicate that for the purposes of calculating the percent yield of normal quality processed product for comparison with other sampling times the normal and spongy categories can be combined as in Figure 2.

The incidence of fragility in the 4 samplings from this location was not nearly as high as those from some of the samplings from Brandon Island in which the degree of sponginess was considerably higher. The total yield of unprocessed roe from the mixed sizes were in the order of those found in Brandon Island.

(c) Wild stocks of herring

The fish obtained through the test fishery from different locations were likewise neither segregated by size nor sampled as frequently as those from the Brandon Island impoundment site. Roes from these samples were used (Table 3) to compare relative maturity levels and incidence of fragility with those from the impoundment sites. The roes from Deep Bay herring caught on February 20 were

considered all immature while those caught 5 days later from the same area were somewhat more mature for processing purposes as were those from the impoundment sites about this time of the year (Tables 1a, 2). The proportion of immature roe from herring sampled at Barkley Sound from early to mid-March was slightly less than that from the Brandon Island impoundment site at the same time of the year. The incidence of fragile roe was nevertheless in the same range as those samples which were frozen properly.

Although the sample from Deep Bay caught on 25 February contained a high proportion of immature roe, no indication of fragility was noted in the normal quality roe. Thus stocks of herring from Barkley Sound, Deep Bay and the upper end of the Trincomali Channel all displayed only low incidences of fragility under proper handling, freezing, frozen storage and processing conditions.

RELATIONSHIP BETWEEN MATURITY AND FRAGILITY

Roe in the immature stages could be readily identified both before and after processing. Inexperienced handlers could be readily shown how to distinguish the difference. Very few, if any, skeins of roe separated as mature during retrieval later proved to be immature following brine curing. Those skeins of roe judged mature in the presence of high levels of immaturity resulted in normal quality final processed product if not complicated by the development of high incidences of sponginess from poor freezing practices. The fragile condition can usually be readily distinguished from immature roe by color, size or texture. During this investigation as well as from studies from previous years, skeins of roe very close to maturity were sometimes difficult to distinguish by the usual criteria from mature roe except that following brine curing the skein structure will crumble under finger tip pressure. These roes are in the fragile condition in which the individual egg cell wall membranes are intact unlike that in the spongy condition. When the amount of immature roe is high it would be expected that the proportion of fragile product will likewise be slightly high. During its course of development immature roe passes from the stage where the eggs are poorly adhesive and the skein structure fails to firm during curing, through a transitional stage and finally become fully mature and adhesive resulting in a firm processed product. Under ideal handling, preservation and processing conditions we have not observed any significant levels of fragility in roe from lots of fully mature herring or even from those which are partially spawned.

EFFECT OF HANDLING AND PROCESSING METHODS ON ROE QUALITY

(a) Influence of brine concentration and firming time on the development of fragility

Herring from Stuart Channel were used to determine the effect of brine concentration and submersion time on the development of fragility in roe from previously unfrozen fish (Table 4). The temperatue of the media was 5± 1°C. In the absence of salt, significant levels of fragility were observed after immersion time of 3 days, and fragility increased up to 5 days. The proportion of immature roe was relatively high in this lot of herring. In seawater strength brine media, the incidence of fragility was lower after 3 days immersion but increased considerably after 5 days to a level exceeding that in the absence of salt. When the brine concentration was increased to a level of 11% and higher, the development of fragility could be controlled more

effectively even after 7 days.

It is of interest to compare the 1984 observations with previously unpublished results on roe from herring maturing at a much later time (April 24). In an experiment carried out in 1978 on unfrozen herring (Table 5), immersion for various times in brine solutions of 2 to 5.3% salt at 1°C resulted in the development of 11 and 14% fragile roe. Although immersion times differed somewhat from that used in Table 4, the level of fragility observed is in the same range. It is also noted that the maturity levels of roe in the earlier studies were higher. The 1984 results confirm the earlier observation, although the herring used in the previous experiments were later maturing stock off the coast of Washington State. At a media temperature of 1°C, immersion in fresh water for 8 days resulted in a very high incidence of fragility; however immersion in saturated brine reduced the development of the condition to approximately the same range as in the later study (Table 4).

(b) Effect of contact with salt solutions of various strength on the development of fragility

In this experiment roe was first brine-firmed by immersion of herring in 11% salt solution. The retrieved roe was then immersed in solutions of varying salt concentrations for up to 24 hours at 5°C before curing (Table 6). The source of fish was the same lot of herring from Stuart Channel. The proportion of fragile roe averaged about 5% after washing in brine solutions ranging in salt concentrations of 3.5% to saturation. In contrast, immersion in fresh water resulted in the development of over 30% fragility. In previous experiments, roes which were not yet firmed were carefully removed from the fish and immersed in fresh water overnight before curing. This resulted in an incidence of fragile roe that was very much higher than that observed in Table 6. Therefore to minimize development of fragility, roe retrieved from the brine firming process should be washed or left in contact with fresh water for as short a period of time as possible or washed in brine solution.

(c) Effect of handling and preservation methods prior to processing on the quality of roe

(i) Dry holding at ambient temperatures followed by preservation by slow and fast freezing (Table 7)

Herring sample that were both slow and fast frozen immediately after delivery to the laboratory, resulted in mainly normal quality roe products with small amounts of spongy skeins and little or no fragility. Post-mortem age before freezing was about 24 hours. Those held at ambient temperature for 2 days and subsequently fast frozen at -30°C resulted in mainly normal quality processed product with the development of only low incidences of both sponginess and fragility. Lengthening the holding time to 5 days, while not increasing fragility, resulted in considerable sponginess. Even those roe products considered in the normal range were slightly soft with some degree of off-odor.

Preservation of herring by slow freezing following 2 days dry storage at ambient temperature resulted in processed roe of similar quality as those preserved by fast freezing. After 5 days storage followed by slow freezing, however, most of the product were fragile and the deterioration was almost complete.

It is of interest to note that in this study the development of spongy roe from slow frozen herring is not as high as that reported previously (Tsuyuki et al. 1977). The longer post-mortem time of the commercially obtained fish used in the previous study could well account for the difference.

(ii) Holding in seawater strength brine at ambient temperatures prior to preservation by freezing (Table 7)

Immersion of fish in 3.5% salt solution for 2 days at ambient temperatures followed by freezing resulted in a higher incidence of spongy roe than dry holding. Slow freezing increased the development of spongy roe. The incidence of fragility was nominal. However, a holding time of 5 days resulted in almost complete deterioration of roe despite subsequent preservation by fast freezing. Most of the product were in the fragile condition.

(iii) Chilled storage followed by brine curing (Table 7)

Roe from herring in 3.5% brine, chilled in CSW system for both 2 and 5 days, developed some degree of fragility as did those firmed in 11% brine for 2 days at a temperature between 3 and 5°C. These studies indicate that brine curing of roe from unfrozen herring, even under chilled storage, result in the development of some degree of fragility despite the fact that the level of immaturity in the samples was extremely low. Similar results were observed in roe from Stuart Channel herring treated in the same manner (Table 4). Dry storage of herring or storage in 3.5% brine for 2 days followed by freezing resulted in the development of somewhat less fragile roe.

(iv) Review of findings

The effect of post-mortem pre-freeze holding time and temperature on the development of fragile processed roe found in this study generally agree with those of Huynh et al. 1984. However there are some differences that need to be considered. Our study shows that herring held for 5 days in the dry state at ambient temperature before fast freezing resulted in the formation of substantial amounts of slightly spongy rather than fragile roe. Those treated in the same way in 3.5% brine deteriorated almost completely into the spongy and fragile category. The uncertainty of segregating spongy and fragile roe without the aid of more sophisticated techniques could in some cases explain part of the differences in finding. Another important source of the difference resides in the relative efficiencies of the freezing systems employed in the two studies. In this investigation the double contact freezing system in the Dole freezer brought the core temperature of herring to -20°C within 6 hours while almost 60 hours were required in the other study. Although spoilage already taken place cannot be reversed further deterioration can be slowed considerably by the use of good freezing practices. There are substantial differences in the quality of roe from herring held dry for 5 days at ambient temperatures and subsequently fast frozen from those frozen slowly (Table 7). Nevertheless, poor storage and freezing practices should be avoided if good roe products are to be produced.

ROE YIELD

To determine the gain in weight of processed roe from once frozen fish, roe weights of all the samples collected from the Brandon Island impoundment site were used (Tables 1a, b and c). In addition, the 3 size ranges

(large, medium and small) were considered separately. The initial values were based on the weights of the unwashed roe extracted from once frozen herring. The final values were based on the weight of the brine processed product after adequate draining.

The gain in weight of roe from large (12.83%) and medium (12.53%) sized herring were about the same while that from small herring was somewhat lower (10.78%). Weight gain of roe from Whaleboat Passage (Table 2), not segregated for size, was 10.63%. For large fish, weight gains in samples with the higher levels of immature roe (collections from 28 February to 12 March) calculated to be 9.57%, while that from the more mature samples (collections from 13 March to 6 April) was 13.92%. For small fish, immature samples (collections from 28 February to 13 March) showed a weight gain of 9.22% while the later more mature samples (collections from 14 March to 6 April) gave a 11.43% gain.

In samples from Whaleboat Passage (Table 2), where the fish collected on 28 February were almost all immature, the weight gain from freezing was 20.79% while the later more mature samples (collections from 22 March to 10 April) gained only 4.92%. This large difference was not observed in the samples from Brandon Island where the levels of immaturity in the early samples were considerably lower. Further studies on much larger sample lots are required to attach more significance to the differences in weight gain in roe from once frozen immature and mature herring. Previous reports show a wide range in values ranging from a low of 2% to highs of 16% (Tsuyuki et al. 1977) and higher (Huynh and Howard 1981).

At ambient temperatures, different pre-freeze holding times of fish in the dry state or in 3.5% brine followed by fast or slow freezing resulted in weight gains ranging from 9 to 16% with some exceptions. Fish held for 5 days in the dry state or in 3.5% brine followed by slow freezing showed the lowest gain of 3 to 4%. The second lot of fish held dry for 5 days, however, resulted in a 10% gain. This lot of herring did not deteriorate to the same extent.

As roe weight before processing can be influenced by drip loss or by storage media (Tsuyuki, unpublished data on 200-300 kg lots of fish) the basis of calculating gain after processing is somewhat uncertain. However, these weight gains are in the same range as those observed for roe from impounded herring which were frozen as soon as possible and which showed minimal drip loss when roe was removed and weighed. These results again emphasize that poor handling and storage conditions prior to freezing influence the weight gain.

Gain in weight of 7 to 8% after processing was observed with roe from unfrozen fish. However, this gain could well be a little high as the initial weights of roe in these samples may have already undergone shrinkage during brine firming. Previous studies which compared the initial weights of green roe removed carefully from herring soon after capture with those removed from fish from the same lot after brine firming indicated significant shrinkage in the roe in the latter (Tsuyuki, unpublished).

CONCLUSIONS

Roe herring from upper Trincomali Channel, Deep Bay and Barkley Sound developed only low incidences of fragile roe product if good practices of handling, freezing, frozen storage and processing, already well known to industry, are applied. Our observations on Barkley Sound samples from previous years are also confirmed by these experiments.

The development of fragility is associated with roe from herring in the early stages after reaching the plateau of roe yield on the gonosomatic index curve.

Nearly mature roe, in the transitional stages of development are at times difficult to identify by size, color or texture from fully mature roe. A higher incidence of nearly mature roe may be encountered when the proportion of immature fish in a sample lot is higher, and it is expected that more may escape detection during grading on a production scale operation.

Storage of unfrozen roe herring in fresh water for even short periods of time or in seawater strength brine for 5 days promoted the development of fragility.

Storage in concentrations of brine 11% or higher for 7 days, the maximum time tested, controlled the development of fragility to a maximum level between 3 to 5%.

Storage of herring at ambient temperatures for 5 days in the dry state followed by preservation by slow freezing or in 3.5% brine followed even by fast freezing result in the development of extensive fragility as well as general deterioration.

Chilled storage of herring in CSW for the 5 days tested still result in a normal grade product.

Prolonged immersion of both fresh or brine firmed roe in water result in the development of extensive fragility.

The application of good freezing and frozen storage practices in the preservation of herring minimizes the development of fragility in roe to a level lower than that found in the product from unfrozen fish under normal processing practices.

The development of fragility in processed roe is associated predominantly with poor handling and storage practice of roe herring or with poor processing techniques.

The gain in weight of processed roe from once frozen herring from impoundment sites ranges from 10 to 14%; from Barkley Sound, 3 to 16%.

ACKNOWLEDGEMENTS

Samplings of herring from the impoundment sites were carried out mostly by Mr. H. Kreiberg, Mr. A. Solmie and personnel of the Mariculture Unit, PBS. Their assistance is greatly appreciated.

We are grateful to Messrs. J. Mitchell, D. Chalmers and L. Webb of the Field Services Branch, and to Mr. R. Parker of Ocean Fisheries Ltd. for arranging and securing other samples of roe herring.

We also wish to thank Messrs. T. Harmon, T. Gemma and B. Harmon for technical assistance in part of the roe herring processing operation.

The authors wish to thank Dr. D. Hay of PBS for the valuable information he provided us on the biology of Pacific herring and for his continuing interest in biological factors which may possibly influence quality of roe.

REFERENCES

Bowers, A.B. and F.G.T. Holliday. 1961. Histological changes in the gonad associated with the reproductive cycle of the herring (Clupea harengus L.). Marine Research No. 5. Dept. of Agriculture and Fisheries, Scotland.

Boyd, J.W., J. Cheng, M.D. Huynh, S.N. Williscroft and H. Tsuyuki. 1980. Roe herring processing: preservation and factors affecting firming of roe. Fisheries and Marine Service. Technical Report No. 921.

Boyd, J.W., S.E. Geiger and B.A. Southcott. 1972. Herring row retrieval and processing. Fisheries Research Board of Canada. Technical Report No. 336.

Brett, J.R. and A. Solmie. 1982. Roe herring impoundment research - report on the 1980/81 studies. Can. Tech. Rep. Aquat. Sci., No. 1061.

Hay, D.E. 1985. Reproductive biology of Pacific herring (Clupea harengus pallasi). Can. J. Fish. Aquat. Sci., 42: 111-126.

Huynh, M.D. and T. Howard. 1981. Comparative yield and quality of roe processed from brined and frozen herring. Tech. Rep. No. 5. Fisheries Technology Division, B.C. Research, Vancouver, B.C.

Huynh, M.D., L. Hildebrand and J. MacKey. 1984. Preprocessing factors affecting quality of herring roe. Tech. Rep. No. 11. Fisheries Technology Division, B.C. Research, Vancouver, B.C.

Kreiberg, H., J.R. Brett and A. Solmie. 1982. Roe herring impoundment research - report on the 1981/82 studies. Can. Tech. Rep. Fish. Aquat. Sci., No. 1149.

Kreiberg, H., J.R. Brett and A. Solmie. 1984. Roe herring impoundment research - report on the 1982/83 studies. Can. Tech. Rep. Fish. Aquat. Sci., No. 1261.

Tomlinson, N., G.A. Gibbard, S.E. Geiger and E.G. Baker. 1975. Storage of roe herring at sea. Fisheries and Marine Service, Technical Report No. 536.

Tsuyuki, H. and J. Cheng. 1985. Quality and yield of roe from impounded herring. Can. Tech. Rep. Fish. Aquat. Sci., No.

Tsuyuki, H., J. Cheng, S.N. Williscroft and M.D. Huynh. 1977. Causes of development of sponginess in roe produced from frozen herring. Fisheries and Marine Service, Technical Report No. 739.

Table 1a. Quality of roe from impounded herring (Brandon Island)

Sampling date (1984)	Herring wt. (kg)	Females (%)	Roe yield (% of females) 1°	2°	Quality in grading (%)* N	SP	FR	UR	Remarks
Feb. 28	L 26.95	55	25.49	26.74	41	2	7	50	very high
	M 26.14	48	20.53	24.09	41	-	6	53	proportion
	S 48.35	32	20.24	22.04	42	1	3	54	of unripe roe
Mar. 2	L 28.45	66	26.55	27.89	75	<1	4	20	" " "
	M 37.45	45	24.37	26.79	70	1	5	24	
	S 52.54	35	18.70	20.47	54	<1	3	43	
Mar. 5	L 30.18	61	25.18	28.46	84	<1	1	15	" " "
	M 35.62	45	19.98	22.81	76	-	-	24	
	S 52.39	36	18.73	20.40	65	<1	1	33	
Mar. 8	L 18.99	60	26.88	30.91	49	34	9	8	High
	M 23.54	54	24.89	29.47	59	18	9	14	proportion
	S 44.22	37	21.29	23.34	77	-	3	20	incidence of spongy roe

1° Roe yield before processing
2° Roe yield after processing
* Proportions estimated by weight: N - Normal, acceptable quality roe
SP - Spongy roe
FR - Fragile roe
UR - Unripe roe (immature roe)

L - large size herring (208 - 225 mm in length)
M - medium size herring (196 - 207 mm in length)
S - small size herring (140 - 195 mm in length)
<-trace

Table 1b. (cont'd)

Sampling date (1984)	Herring wt. (kg)	Females (%)	Roe yield (% of females) 1°	2°	Quality in grading (%)* N	SP	FR	UR	Remarks
Mar. 12	L 76.45	58	28.89	31.72	64	20	7	9	Grading of fragile roe is difficult due
	M 47.92	51	25.88	28.57	65	17	6	12	
	S 88.29	33	21.82	22.88	42	27	9	22	
Mar. 13	L 78.55	62	27.86	31.42	65	24	4	6	to high proportion
	M 59.70	49	25.46	28.56	62	21	7	10	
	S 91.57	32	22.37	25.27	61	13	4	22	of spongy roe
Mar. 14	L 72.77	57	29.18	32.46	66	30	-	4	
	M 37.28	51	27.36	30.31	83	9	1	7	
	S 101.97	32	23.43	26.22	81	4	1	14	
Mar. 15	L 61.48	57	29.14	35.04	85	10	1	4	
	M 64.36	46	26.48	29.45	83	11	1	5	
	S 93.39	33	23.29	24.80	84	2	-	14	
Mar. 16	L 50.14	61	29.02	34.04	94	2	-	4	
	M 56.21	46	26.50	29.40	90	7	-	3	
	S 85.85	33	22.91	25.50	84	1	1	14	
Mar. 17	L 69.72	53	28.58	31.86	97	1	<1	2	
	M 53.61	48	25.69	29.57	94	1	<1	5	
	S 90.87	31	22.01	26.01	88	<1	<1	12	
Mar. 18	L 66.06	55	28.60	32.47	62#	36	1	1	#Generally roe appeared to be softer in texture
	M 53.61	48	27.24	30.70	74	19	3	4	
	S 122.46	34	23.61	26.27	56	28	7	9	

Table 1c. (cont'd)

Sampling date (1984)	Herring wt. (kg)	Females (%)	Roe yield (% of females) 1°	2°	Quality in grading (%)* N	SP	FR	UR	Remarks
Mar. 19	L 60.25	56	28.06	32.20	94	4	1	1	Normal in
	M 61.47	49	26.49	29.84	92	5	<1	3	quality
	S 100.98	30	21.89	25.55	90	3	<1	7	
Mar. 20	L 66.13	54	27.91	32.58	98	1	<1	1	Good quality
	M 53.85	48	25.72	29.29	97	<1	<1	3	roe in high
	S 94.77	31	22.60	25.90	93	<1	<1	7	proportion
Mar. 21	L 27.74	61	29.69	33.69	96	1	1	2	
	M 28.16	47	26.34	29.97	99	1	<1	<1	
	S 46.32	28	22.79	25.53	96	1	1	2	
Mar. 24	L 21.56	59	28.80	31.58	95	<1	<1	4	
	M 34.80	45	26.33	29.04	97	2	<1	1	
	S 59.97	32	22.84	25.90	95	<1	<1	4	
Mar. 27	L 26.84	61	27.82	33.00	94	5	<1	<1	Normal in
	M 35.51	50	25.65	28.58	97	2	<1	<1	quality
	S 32.60	36	22.70	25.45	96	2	<1	2	
Mar. 30	L 28.59	61	28.24	31.42	95	3	<1	2	
	M 37.54	47	24.77	28.40	99	<1	-	<1	
	S 51.01	40	21.44	24.12	98	1	<1	<1	
Apr. 2	L 27.86	55	27.82	31.00	97	3	-	-	
	M 39.09	47	25.63	28.37	96	3	<1	-	
	S 50.51	30	23.72	25.01	89	10	<1	-	
Apr. 6	L 34.76	51	28.05	31.52	90	10	-	-	
	M 29.62	38	24.66	26.91	99	<1	-	-	
	S 45.34	28	22.29	23.04	98	2	-	-	

Table 2. Quality of roe from impounded herring (Whaleboat Passage)

Sampling date (1984)	Herring wt. (kg)	Females (%)	Roe yield (% of females) 1°	2°	Quality in grading (%)* N	SP	FR	UR	Remarks
Feb. 28	28.04	54	21.12	25.51	3	-	-	97	Very high proportion of unripe roe
Mar. 13	29.78	44	24.16	27.92	83	3	1	13	
Mar. 22	33.83	41	28.80	30.18	96	1	2	1	Normal in quality
Apr. 10	16.70	35	29.58	31.07	96	2	2	-	From fish farm

Table 3. Quality of roe from wild stock herring

Sampling date (1984)	Herring wt. (kg)	Females (%)	Roe yield (% of females) 1°	2°	Quality in grading (%)* N	SP	FR	UR	Remarks
Feb. 20	19.78	37	21.55	-	-	-	-	100	a
Feb. 25	19.57	49	23.00	25.50	18	-	-	82	a
Mar. 8	31.67	51	26.94	30.23	92	-	2	6	b
Mar. 12	40.82	48	27.13	32.28	98	-	1	1	c

a. From Deep Bay, Area 14. Very high proportion of unripe roe.
b. From Chow Island, Barkley Sound, Area 23.
c. From Pipestem Inlet, Area 23.

Table 4. Effect of brine concentration and holding time on the development of roe fragility (temperature, 5± 1°C)

Brine conc. (%, w/v)	Firming time (days)	Roe maturity % immature roe by number	by weight	% Fragile roe after curing by weight
0	3	23.89	19.23	6.32
	5	23.70	15.59	8.37
3.5	3	15.89	13.99	2.90
	5	11.58	8.96	11.10
11.0	3	13.80	9.34	4.80
	7	19.63	13.19	4.14
16.0	3	21.40	19.60	2.90
	7	20.40	14.80	4.20
26.0	3	13.30	11.73	4.16
	7	12.70	7.40	4.70

Table 5. Effect of brine concentration and holding time on the development of roe fragility (temperature, 1°C)

Brine conc. (%, w/v)	Initial fish wt. (kg)	Firming time (days)	Roe maturity % immature roe by number	by weight	% Fragile roe after curing by weight
0	27.3	8	16.90	14.30	63.80
2.0	30.0	6	5.60	4.20	12.90
3.7	30.0	4	6.00	5.10	10.80
5.3	30.0	4	3.40	8.20	14.40
26.0	30.0	3	9.00	11.80	5.80

Seine caught herring, about 700 kg, obtained from Blaine, Washington, U.S.A. on April 24, 1978. Post-mortem storage time was about 18 - 22 hours on ice. In each set, approximately 30 kg of herring were used.

Table 6. Incidence of fragility in roe from herring firmed in 11% brine followed by prolonged washing in salt solutions of various strengths.

Brine conc. (%, w/v)	Roe maturity % immature roe by number	by weight	% Fragile roe after curing by weight
0	15.80	8.70	31.30
3.5	15.40	10.60	4.80
8.0	14.30	7.50	5.00
11.0	12.50	11.30	7.60
16.0	18.60	11.30	5.70
26.0	12.30	10.80	1.80

Table 7. Effect of handling and preservation conditions on the quality of roe[a]

Handling and processing Condition	Weight gain[b] (%)	Herring wt. (kg)	Females (%)	Roe yield[c] 1°	Roe yield[c] 2°	N	Grade (%)[d] SP	FR	UR
Control[e] (FF)	113.52	82.56	51	27.35	31.05	98	<1	<1	1
(SF)	112.87	59.92	50	27.34	30.86	96	3	-	1
Dry, ambient temp. (FF)									
2 days	112.77	32.52	49	28.03	31.61	94	2	2	2
5 days	111.25	22.50	52	27.56	30.66	70[f]	28	1	1
Dry, ambient temp. (SF)									
2 days	115.63	33.20	53	27.12	31.36	96	3	1	0
5 days	110.31	28.71	51	27.06	29.85	26	---74[g]--		<1
5 days	102.92	32.13	46	25.32	26.06	nil	---99[g]--		1
3.5% brine, ambient temp. (FF)									
2 days	110.80	28.35	52	27.60	30.58	93	5	2	<1
5 days	103.77	33.27	52	25.73	26.70	nil	---99[g]--		1
3.5% brine, ambient temp. (SF)									
2 days	109.31	29.45	51	27.39	29.94	86	10	3	1
CSW, 3.5% brine, -1°C									
2 days	108.24	65.32	50	24.99	27.05	95	-	4	1
5 days	106.55	99.02	48	23.97	25.54	95	-	4	1
11% brine, 3-5°C, brine firmed									
2 days	107.68	46.80	53	25.40	27.35	95	-	3	2

a - Herring from Barkley Sound, 13 March 1984
b - Processed roe weight / unprocessed roe weight x 100
c - % by weight based on females. 1° = before processing. 2° after processing
d - proportion by weight
e - frozen immediately after delivery to laboratory
f - slightly soft texture and slightly off-odour
g - spoilage condition, off-odour
N, SP, FR, UR - see previous tables
< - less than

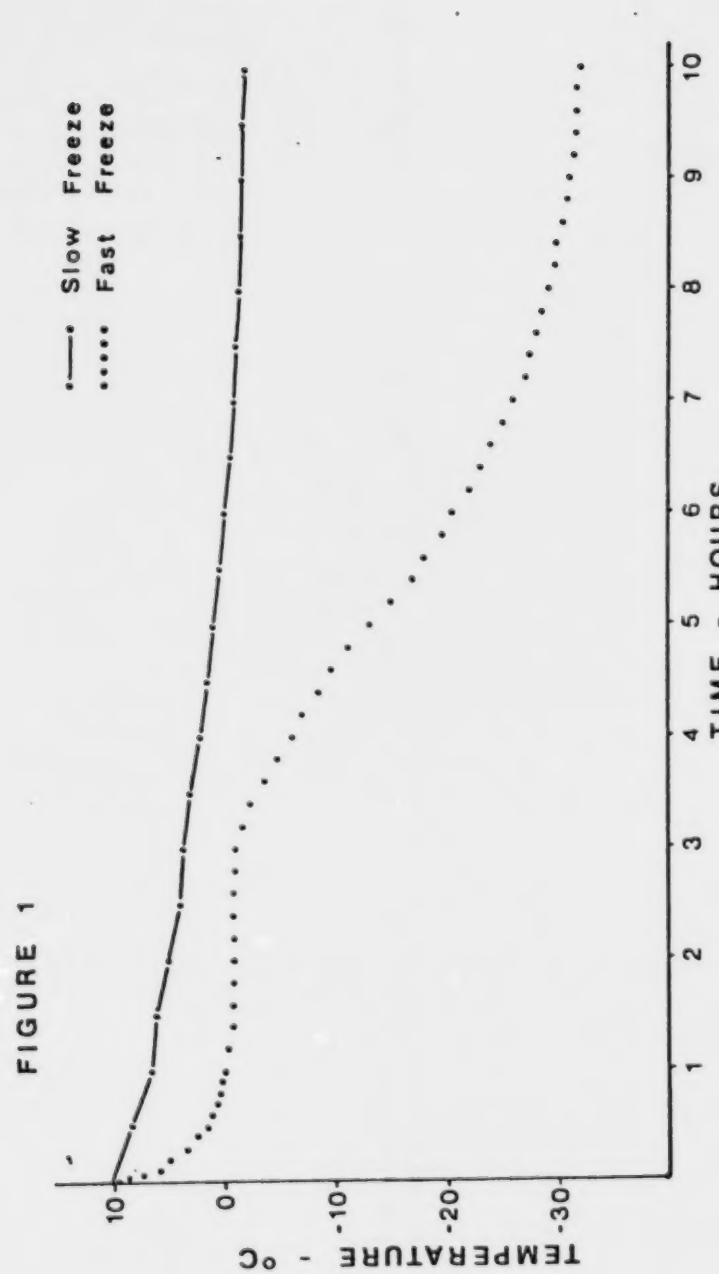
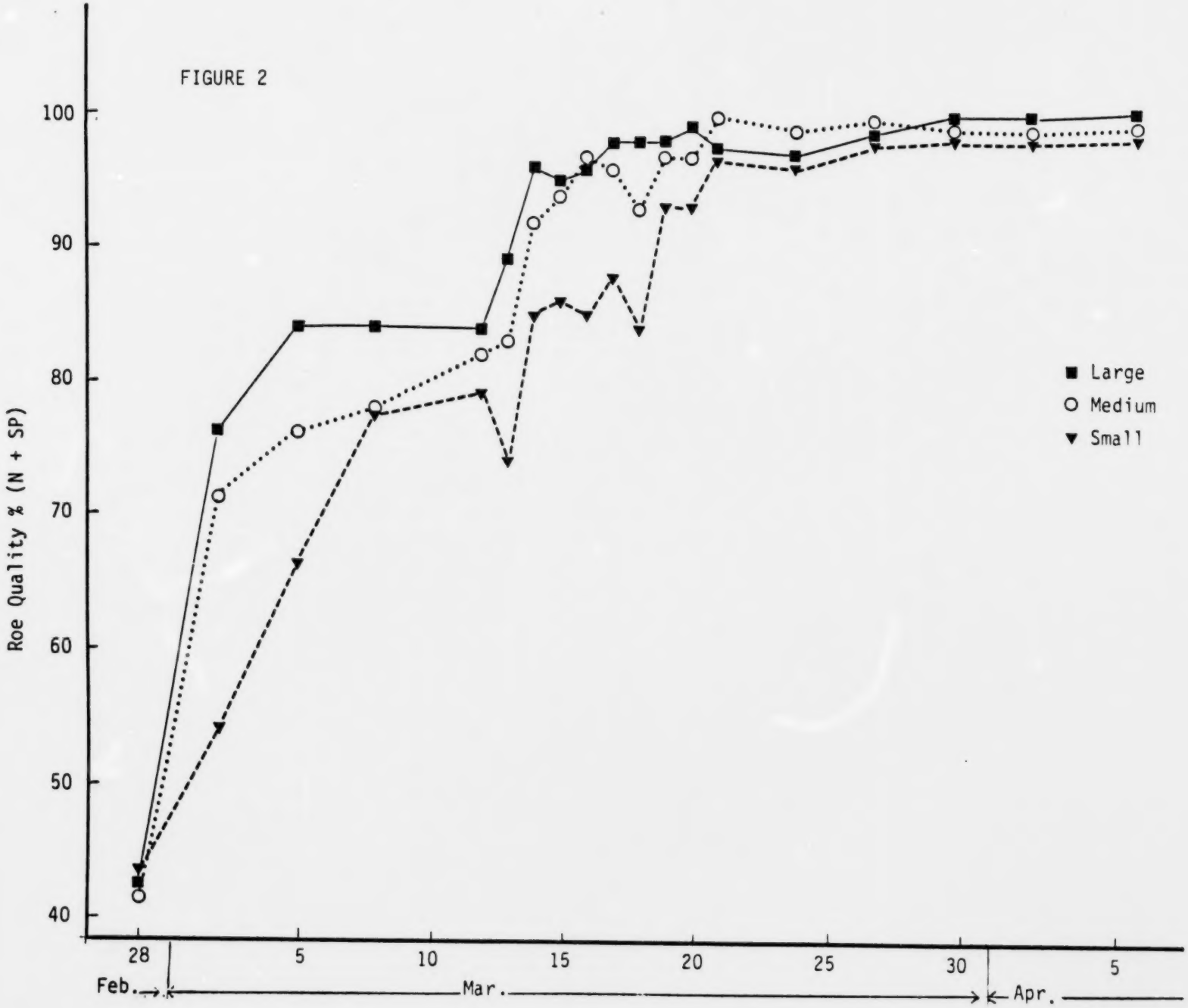


Fig. 1. Slow and fast freezing rates of herring stocks.

Fig. 2. Increase in the proportion of normal grade processed herring roe (normal + spongy) with increasing maturation of roe.

FIGURE 2


Roe Quality % (N + SP)
100
90
80
70
60
50
40
28
Feb.
5
10
15
20
25
30
Mar.
5
Apr.
Large
Medium
Small

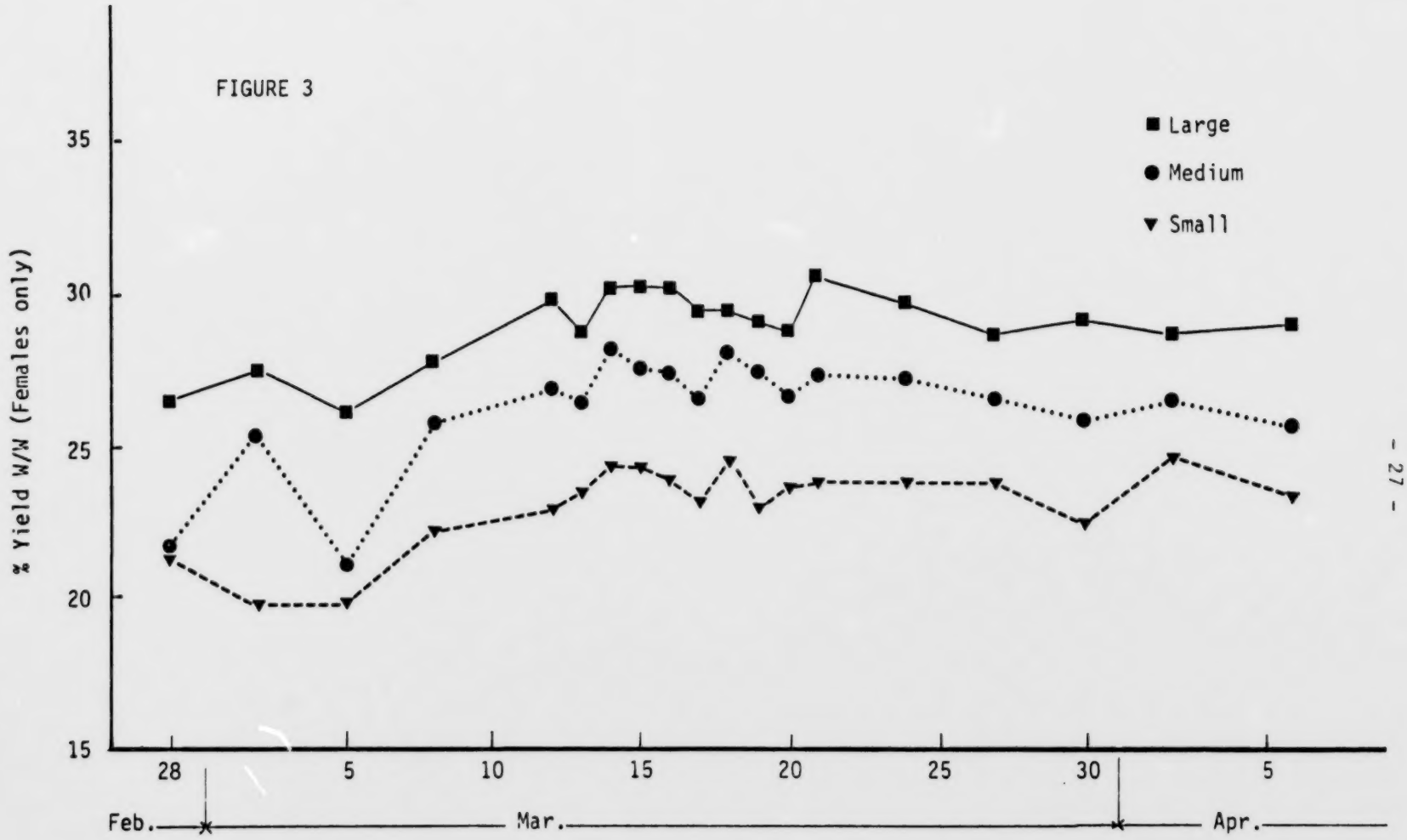
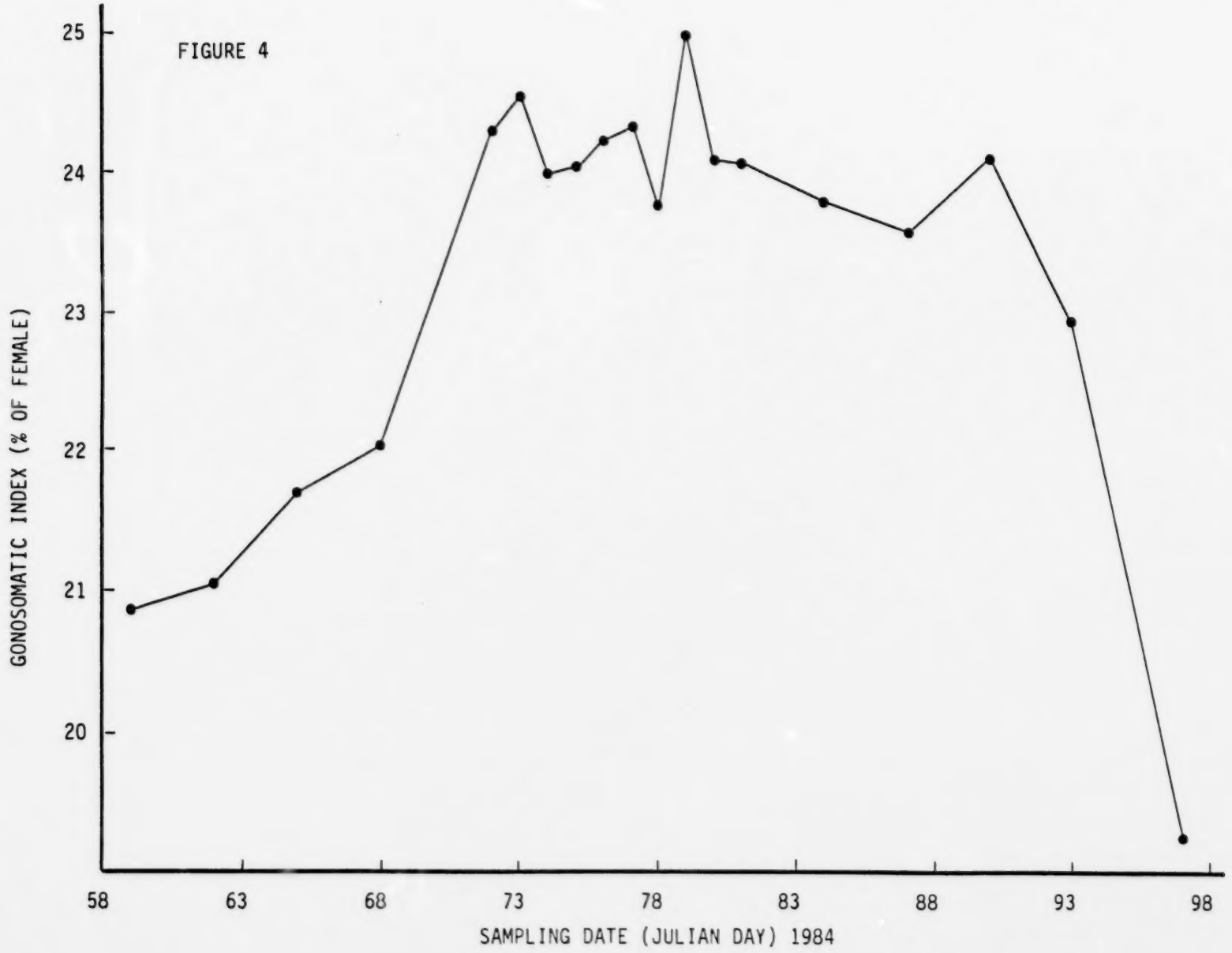


Fig. 3. Differences in yield of roe (w/w, females) from herring of different size during maturation.

Fig. 4. Gonosomatic Index monitoring of impounded herring, 1984.

FIGURE 4


25
24
23
22
21
20
GONOSOMATIC INDEX (% OF FEMALE)
58
63
68
73
78
83
88
93
98
SAMPLING DATE (JULIAN DAY) 1984